THERMAL ENERGY TRANSFER THROUGH ALL CERAMIC RESTORATIONS

by

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A manuscript submitted to the Faculty of the
Comprehensive Dentistry Graduate Program
Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
in partial fulfillment of the requirements for the degree of
Master of Science
in Oral Biology

June 2016

Naval Postgraduate Dental School
Uniformed Services University of the Health Sciences
Bethesda, Maryland

CERTIFICATE OF APPROVAL

MASTER'S MANUSCRIPT

This is to certify that the Master's Manuscript of

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has been approved by the Examining Committee for the manuscript requirement for the Master of Science degree in Oral Biology at the June 2016 graduation.

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ACKNOWLEDGEMENTS

Special Thanks To:

- CAPT Marc Arena
- CAPT David Hartzell
- CAPT Glen Imamura
- CDR Andrew Avillo
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JUN 2016

NAVAL POSTGRADUATE DENTAL SCHOOL
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2016

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Christopher D. Parks D.D.S.,
COMPREHENSIVE DENTISTRY 2016

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CLINICAL RELEVANCE STATEMENT

This pilot study provided useful information comparing the thermal energy transfer through 3 all-ceramic restorative materials to natural teeth.

ABSTRACT

INTRODUCTION: The literature has demonstrated that cold testing with 1,1,1,2-tetrafluoroethane (TFE) can be used to assess the pulp vitality of teeth restored with full coverage restorations. In recent years, there has been an increased use of the all ceramic crowns. However, there is no clinical guidance for cold testing of teeth restored with these newer materials.

PURPOSE: This pilot study compared the thermal conductivity of 3 ceramic restorative materials to natural teeth.

MATERIALS AND METHODS: Thermoprobes (T-type, Omega) were inserted into the pulp chamber of 3 extracted human premolars filled with a heat conducting media (Omegatherm 201, Omega). A #2 cotton pellet saturated with TFE (Endo Ice) was applied to buccal enamel at the height of contour and the temperature change was recoded (HH-2000, Omega). To mimic the restored tooth, 1.5mm of enamel at the buccal height of contour of all the teeth was removed. A 12x12x1.5mm thick block of lithium disilicate (IPS e. max), zirconium oxide (Zirconia), or

hybrid ceramic (Vita Enamic) was placed on the prepared enamel and the temperature recorded. For all tests, the temperature change was recorded every 10 secs. for two minutes and repeated 3 times. For simulated restored teeth, the different ceramic blocks were randomly tested and heat conducting media was used to simulate the cement layer.

RESULTS: Temperature changes in natural teeth were consistent and demonstrated an exponential decrease with time. Although similar trends were recorded for the three test ceramic, drastic intra and inter-sample variances were found.

CONCLUSIONS: Preliminary data suggested that similar to the natural tooth, the cold test can be used to test the vitality of teeth restored with all ceramic restorations.

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CHAPTER I: INTRODUCTION

In a survey conducted by the American Dental Association, dentist reported delivering more than 33 million crowns in 2005 (American Dental Association, 2006). Assuming these numbers have stayed consistent and that 10-15% of all crowns placed would develop necrotic pulps (Felton, 1989; Valderhaug et al., 1997), there are a minimum of 3.3 million potential teeth requiring pulp vitality/sensibility testing in the United States annually. Trautmann et. al., stated most practitioners believe many teeth restored with full-coverage restorations require endodontic treatment within 5-10 years (Trautmann et al., 2000a; Trautmann et al., 2000b). In 2004 Miller et al., determined that cold testing can be conducted through porcelain fussed to metal crowns, all porcelain crowns (empress) and gold crowns using 1,1,1,2 tetrafluroethane (TFE)(Miller et al., 2004). In recent years due to improved technology, and advances in milling processes, there has been an increase use of all ceramic materials and the development of hybrid ceramic materials. As these products evolve so do their physical properties such as increased fracture resistance, improved resistance to erosion and improved resistance to thermal shock (Giordano and McLaren, 2010). The purpose of this study is to determine the thermal conductivity of these materials to verify that if they too can be thermally tested for sensibility.

CHAPTER II: REVIEW OF THE LITERATURE

Pulp Vitality Testing Methods

Copious amounts of research have been conducted to establish the most reliable methods to determine pulp vitality/sensibility. These methods include hot and cold thermal testing, electrical pulp tests and laser Doppler flowmetry. Laser Doppler systems measure the true vitality of the tooth by measuring the blood flow throughout the pulp chamber

(Rowe and Pitt Ford, 1990). Despite their repeatability and accuracy reported by Chen and Abbott (Chen, 2011), they have not become a common measuring tool for the general dentist because of the cost of the apparatus and the test can be time consuming.

The remaining tests focus on the sensibility of the tooth. In order to elicit a positive response the pulp must be present. These tests can be patient dependent, but typically no response is associated with a pulpless tooth of advanced pulpal necrosis (Fuss et al., 1986). For example, with electric pulp testing the amount of current required to elicit a response does not directly correlate to a histological status or disease process. A positive response only expresses that there is a viable nerve fibers located within the pulp (Seltzer et al., 1963). However, electronic pulp testing can be very beneficial do to its high negative predictive value of .90 (Jespersen et al., 2014). If a tooth has a negative response or no response to electronic pulp testing, there is a high predictive chance that the tooth is necrotic.

The focus of this study is in the thermal response of teeth restored with zirconia and lithium disilicate. In a study by Villa-Chavez et. al., both of the thermal tests had higher negative predictive values and sensitivity than electrical pulp testing (Villa-Chavez et al., 2013). While heat testing shows reliable responses to sensibility testing it does have some notable complications. Studies show that gradual temperature changes do not elicit rapid responses, but do eventually stimulate a pain response through C-fibers (Mengel et al., 2000; Bender, 2000). The most superior pain reactions are elicited through the A-delta fibers with extreme temperature differences (Bender, 2000). Zach and Cohen stated that a 5.5 degree Celsius change over ten seconds causes a 15% likely hold of irreversible pulpitis, an 11.1 degree Celsius change over ten seconds cause a 60-70% likely hold of irreversible pulpitis, and a 30 degree Celsius change over ten seconds cause a 100% likely hold of irreversible pulpitis (Zach

and Cohen, 1965). On the other hand, Rickoff et. al. study showed there was no change in pulpal health to teeth exposed to cold testing for up to five minutes (Rickoff et al., 1988).

Other earlier studies showed that there was no damage to pulp tissue at 11 degrees Celsius (Langeland et al., 1968). In fact, U. Frank stated that pulpal degeneration would only occur if the tissue was frozen (Frank et al., 1972). With an accuracy calculation of 90.4%, Jespersen, Holstein, and Williamson found cold testing to be the most reliable sensibility test with a 0.916 sensitivity, 0.896 specificity, 0.862 positive productive value and a 0.937 negative predictive value (Jespersen et al., 2014). This study confirmed results from Peterson et. al. in 1999 and Villa-Chavez et. al. in 2013. The Villa-Chavez et. al. study reported an accuracy of 94% and a reproducibility of 88% (Villa-Chavez et al., 2013). Due to the superior accuracy, reproducibility, negative predictive value and decreased potential for irreversible damage, cold testing will be the test of choice for this study.

Many studies have been published exploring the most accurate and feasible means for conducting cold tests. Testing mediums include ice, CO_2 snow sticks, dicholorodifluoromethane (DDM) refrigerant spray and 1,1,1,2 tetrafluoroethane refrigerant spray (TFE). The latter has replaced dicholorodifluoromethane as the refrigerant spray of choice due to its increased environmental safety (Jones et al., 2002). In 1976 Fulling and Andreasen, reported that CO_2 out performed ice by producing more consistent pupal responses (Fulling and Andreasen 1976). A study showed CO_2 snow has been reported as an efficient method for delivering up to -58º C to the tooth (Ingram and Peters, 1983). While some studies report that the CO_2 and ice can produce the greatest change in temperature, this is over a 2-5 minute period (Augsburger and Peters, 1981; Peters et al., 1986; Ingram and Peters et al). It has even been stated that TFE ceased reducing temperature after on minute where as both ice and CO_2 ice continued to

decrease temperature beyond a two minute test cycle (Miller et al., 2004). However as stated earlier, the most affective thermal sensibility test is conducted through a rapid temperature change (Mengel et al., 1993; Bender, 2000). Several studies suggest that TFE is the testing medium of choice for rapid thermal temperature change (Herrera et al., 2008; Jones, 2002; Miller et al., 2004; White and Cooley, 1977). Miller et. al. in vivo study reported that TFE expressed the greatest thermal change through gold, all porcelain crowns and porcelain fused to metal crowns with in the first 30 seconds (Miller et al., 2004).

In his study Miller used a technique described by D. M. Jones in 1999. Jones determined that using a #2 cotton pellet with DDM (now replaced with TFE) produced the greatest temperature in the pulp chamber of a mandibular premolar in vivo (Jones et al., 2002). The #2 cotton pellet was sprayed for 3 seconds from a distance of 5mm (Jones et al., 2002). The results in this study showed that applying refrigerant spray directly to a #2 cotton pellet was the most efficient way to achieve a rapid temperature change to the tooth surface.

Restorative Materials

Porcelain has been used in dentistry for centuries. Typically, they are classified by their microstructural composition. The three terms used to classify the different components are glass, ceramic (crystalline material) and porcelain (a mixture of glass and crystalline material). Giordano and McLean (2010) categorized ceramics in four categories on a sliding scale based on the amount of glass and the amount of crystalline material in the ceramic. The first category is a pure glass based material and it was the first ceramic used in dentistry. Divided into three subcategories, the second group is comprised of differing ratios of glass and crystalline material. The primary crystals in this category are placed in a glass matrix through a powder /liquid mix or grown within the glass matrix during a second heating phase.

In the study by Miller et al. (2004), he evaluated the sensibility testing through the ceramics in the first two subcategories. He tested the low-to-moderate leucite containing ceramics that are primarily used to veneering over a metal sub-structure. The original versions of this ceramic had varying sizes of leucite particles, but newer generations have reduced the size and narrowed the range of particles in the matrix. This evolution in ceramics improved the control of the coefficient of thermal expansion, improving compressive strength, flexural strength and decreasing the crack propagation over the original pure glass ceramic materials (Giordano and McLaren, 2010).

The second subcategory highlighted in Miller's study looked at a ceramics with approximately 50% leucite contained in the glass matrix. The Empress (Ivoclar Vivadent) material starts out as a homogenous glass matrix and during a second heating phase the crystals are nucleated and grown within the matrix. This puts the crystals a compressive stress around the crystals and as a result this material has increased fracture resistance, improved thermal shock resistance and resistance to erosion. Another added advantage to arise in this subcategory is these are the first ceramics to be pressed or machined from solid blocks. This improves the fracture resistance over the powder/liquid ceramics by reducing the amount of impurities in the processing of the ceramics (Giordano and McLaren, 2010).

Both pressed and machinable IPS e.max ceramics will be evaluated in this study. The two ceramics are versions of the third subcategory of the glass-based system with crystalline second phase. These ceramics have a lithium silicate glass matrix with approximately 70% lithium-disilicate crystal fill. The micron size and dense fill increase the flexural strength the to 360 MPa which is three times that of Empress (Giordano and McLaren, 2010).

The third composition category described by Giordano and McLaren are the Interpenetrating Phase Ceramics. These ceramics were developed as an alternative to the metal used as substructure. There flexural strength can range from 350-650 MPa depending on the crystals used to fill the matrix. They have been used as single unit restorations but do to their low translucency and reduced esthetic appearance they are only recommended in the posterior region (Giordano and McLaren, 2010).

The second material that will be evaluated in this study are the polycrystalline solids which comprises the fourth composition category depicted in the paper by Giordano and McLaren. These ceramics are formed by directly sintering the crystals eliminating the need for the glass matrix. The material is dense, free of porosities and glass free. The zirconia version of this material can have flexural strengths up to 1100 MPa (Giordano and McLaren, 2010). They can be milled in an oversized block or in a fully sinter block. Typically, the over-sized block is used for milling to reduce the milling time and wear in the carbide burs (Kelly JR and Benetti P, 2011).

More recently Russell Giordano teamed up with Vita to develop a hybrid material called Vita Enamic. The company's website (www.vitanorthamica.com) , states the material is a combination between ceramic and composite materials. The material can be mill chairside and delivered to the patient on the same day.

CHAPTER III: MATERIALS AND METHODS

The methods for this study were modified and adapted from the design used in Miller et al., 2004. Four extracted human premolars stored in 0.2% sodium azide solution were collected from WRNMMC Oral Surgery Clinic. Radiographs were used to verify adequate space in the pulp chamber for the placement of a thermocouple probe with a diameter of 0.5mm, and to verify

uniform enamel-dentin thickness on the facial surface of all samples (Figure 1). Then the teeth were mounted in orthodontic resin blocks using a gig 12mm wide, 40mm in length and 15mm. To maintain the tooth's orientation the lingual half of the root was secured in a 3mm thick acrylic base while maintaining apical access into the root canal system. Once the acrylic set the remaining tooth structure was covered to the buccal height of contour. The roots were then sectioned 5 mm from the cementoenamel junction, and all pulpal material will be removed with barbed broaches. Before the thermocouple is placed in the pulp chamber (Type T, Omega Engineering), they will be filled with a thermal conductive medium (Omegatherm "201" High Temperature High Thermal Conductivity Paste, Omega Engineering, Stamford, CT) using a 1 ml syringe (Excelint International, Los Angeles, CA) and a Lentulo spiral filling instrument (Star Dental, Philadelphia, PA). Then the thermocouple will be securely placed in the pulp chamber with sticky wax. Radiographs were used to verify the adequate placement of the thermocouple within the pulp chamber against the most coronal extent of the pulp-dentin surface opposite the facial testing surface (Figure 2). Thermal tests were completed at room temperature using a bench-top apparatus depicted in Figure 3 and 4. Baseline temperature for each sample was established using a water bath set to 37 degrees Celsius.

Previous studies have shown that TFE proved to be the most rapid, and efficient thermal test agent on the market, in comparison with other materials such as ice, dry ice, etc. (White and Cooley, 1977; Jones, 1999; Jones et al, 2002; Miller et al, 2004; Herrera de Morais et al, 2008). For this reason, in this study TFE was the thermal testing agent of choice.

Thermal test were conducted on the middle third of the facial surface for 120 seconds, and the intrapulpal temperature change was measured at 10-second intervals with a logging thermometer (HH2002AL, Omega Engineering). Using TFE (Endo Ice, Hygenic., Akron, OH)

on a saturated #2 cotton pellet held with Kelly straight hemostats (Hu-Friedy, Chicago, IL), base line thermal tests was taken on the four intact premolar crowns before they are prepared for testing with restorative material. The two-minute cycles was conducted to determine the time needed to reach its peak thermal change.

Two millimeters of reduction from the facial height of contour on each tooth was trimmed using a parallel prepping device . The 1.5mm thick lithium disilicate (IPS e.max CAD, Ivoclar Vivadent, Amherst, N.Y.) and hybrid dental ceramic (Vita Enamic, Vita North America) sets were fabricated by trimming manufactured blocks using a table saw. The zirconia (Ceramill Zolid, Amann Girrbach) set were designed and milled using Amann Girrbach software.

CHAPTER V: RESULTS

Graph 1 shows the average temperature change in degrees Celsius over time in seconds for the restorative materials and the natural teeth. The temperature is decreasing over time for each of the materials and the natural teeth. Graph 2 shows the temperature in degrees Celsius over time in seconds for each nine natural tooth cycles. From left to right the cycles are tightly grouped together and represent a repeatable pattern. Graph 3 shows the temperature in degrees Celsius over time in seconds for each of the IPS e.max cycles. While from left to right the temperature is decreasing the pattern is not as finely grouped as with the natural teeth. Graph 4 shows the temperature in degrees Celsius over time in seconds for each of the IPS ZirCAD cycles. Here temperature is decreasing from left to right but again the trials are not as tightly groups as in the natural teeth. Graph 5 shows the temperature in degrees Celsius over time in seconds for each of the enamic cycles. As with the e.max and zirconia trials, the cycles are not as tightly grouped. Table 1 shows the average temperature change for the restorative materials and natural teeth at ten second and 30 seconds.

CHAPTER VI: DISCUSSION

The temperature for each of the material appears to be changing very similarly to the natural tooth, but with the small sample size this may be hiding important details.
The difference between the cycles can be equated to the different dentinal thickness of each specimen and the quality of the #2 cotton pellets. When testing the restorative materials, there were inconsistent delays in applying the charged ENDO ICE to the restorative materials. This could have been an experimental design flaw having only one investigator conducting the trials.

However, as stated in Bender's research (2000) the most superior pain reactions are elicited when rapid extreme differences in temperature are applied to the crown of the tooth. So, by looking at the average temperature change in degree Celsius over 10 seconds and 30 seconds for each of the materials and compare this to the natural teeth, we notice there are very similar readings. The average temperature decrease in natural teeth at 10 seconds was 6.8 degrees Celsius and at 30 second 13.1 degrees Celsius. Both the e.max and the Zirconia materials had slightly high temperature decreases at 10 seconds and 30 seconds compared to the natural teeth. The enamic material had the same average temperature change at 10 second as the natural teeth but at 30 seconds slightly less of a temperature change was noted.

Temperature changes in natural teeth were consistent and demonstrated an exponential decrease with time. Although similar trends were recorded for the three tested materials, drastic intra and inter-sample variances were detected.

The average decrease in temperature for each of the all-ceramic materials appears to be similar to the natural tooth, but at this time no significant statistical statements can be made due to the small sample size of this pilot study.

CHAPTER VII: CONCLUSION

Preliminary data suggested that similar to the natural tooth, the cold test can be used to test the vitality of teeth restored with all-ceramic restorations.

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CHAPTER IX: FIGURES

Figure 1: Radiograph of premolar

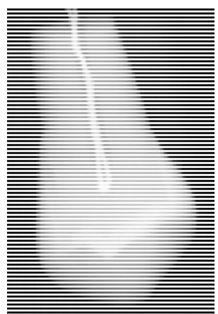


Figure 2: Radiograph of premolar with probe

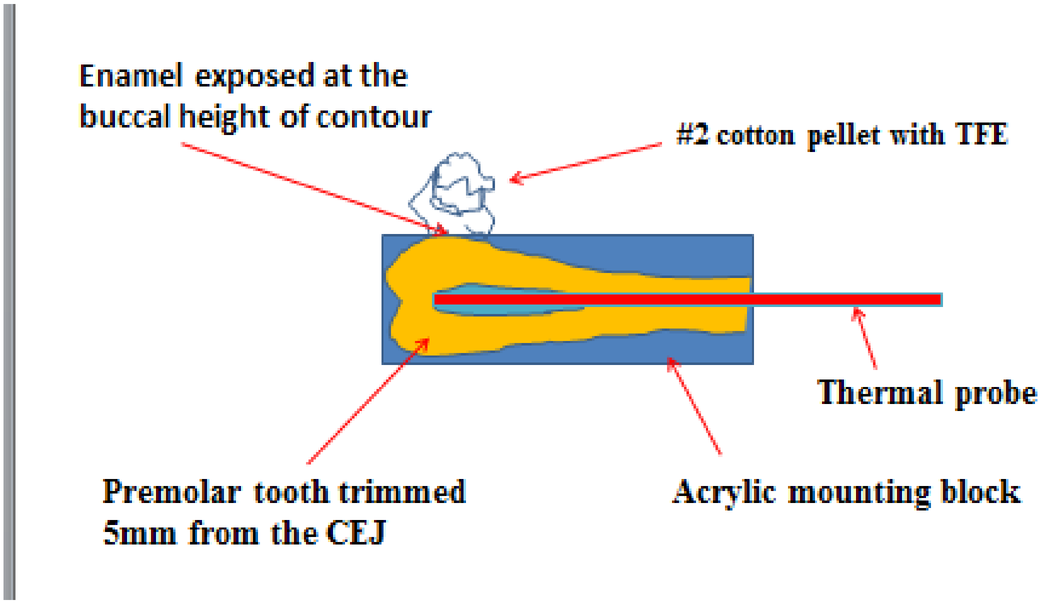


Figure 3: Diagram of natural tooth thermal testing

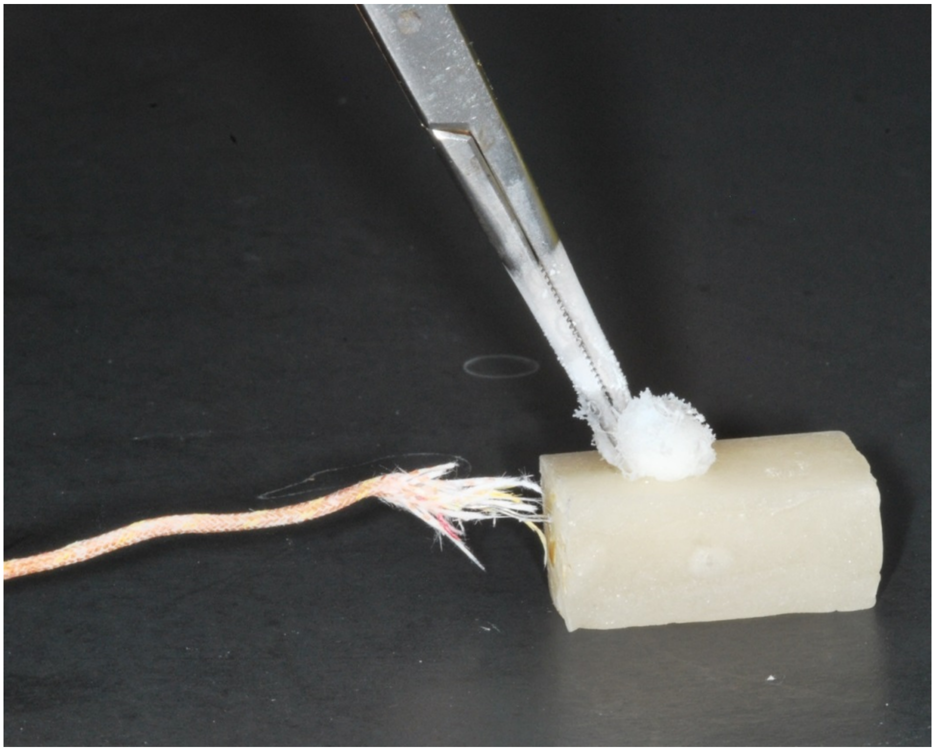


Figure 4: Natural tooth thermal testing

Figure 5: Restorative material trimmed to 1.5x10x10mm blocks

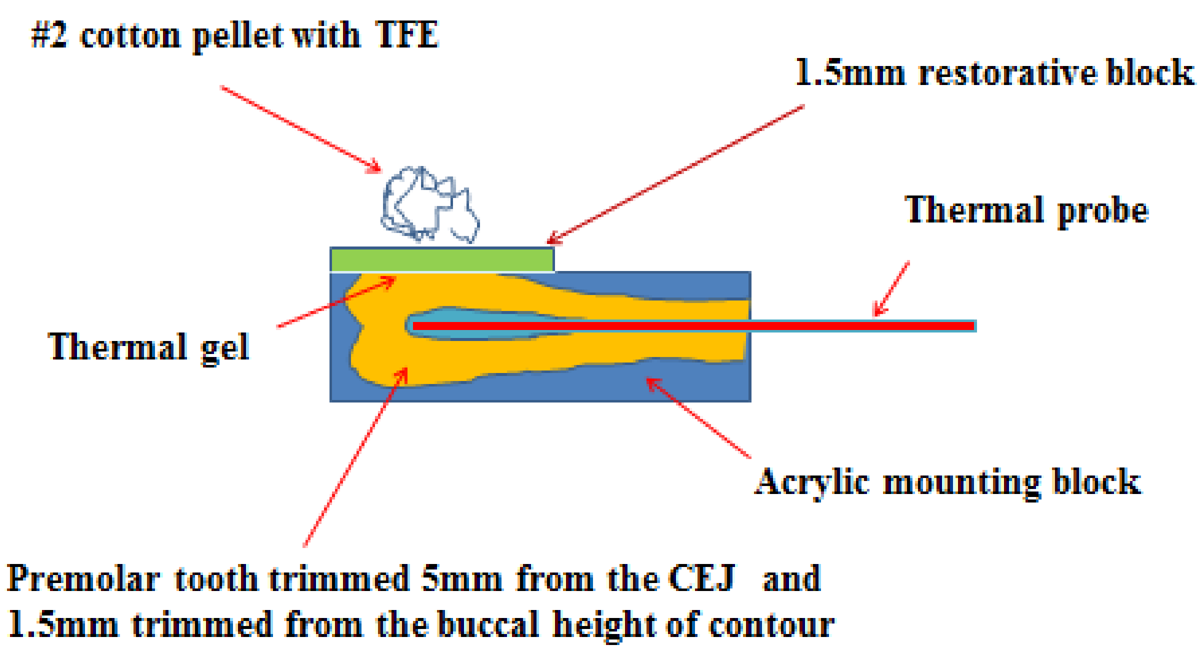


Figure 6: Experimental diagram of thermal testing with restorative material

a.


b.

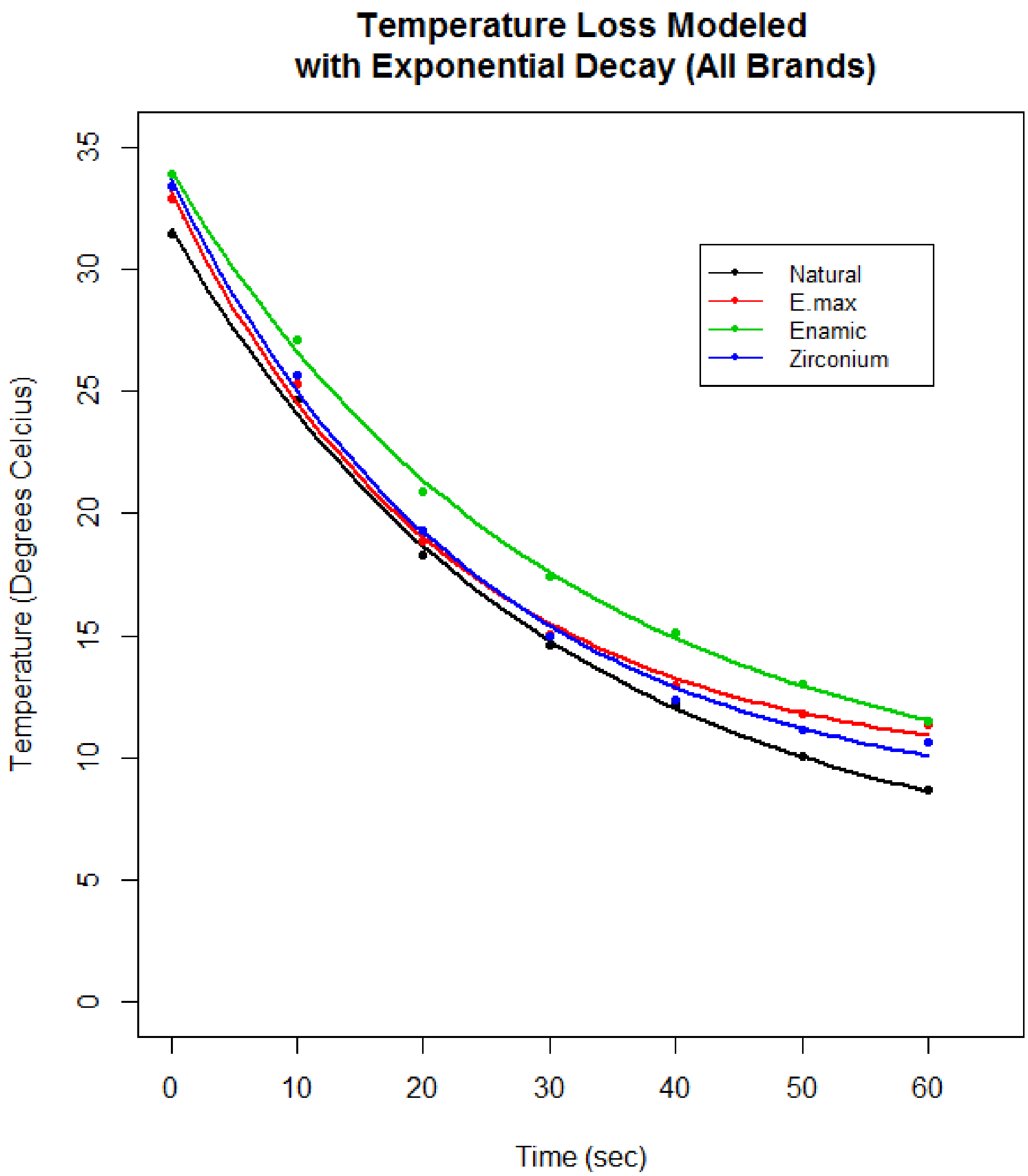
Figure 7: a. Thermal testing with restorative material; b. image of 1.5 mm removed from the buccal height of contour

CHAPTER X: TABLES

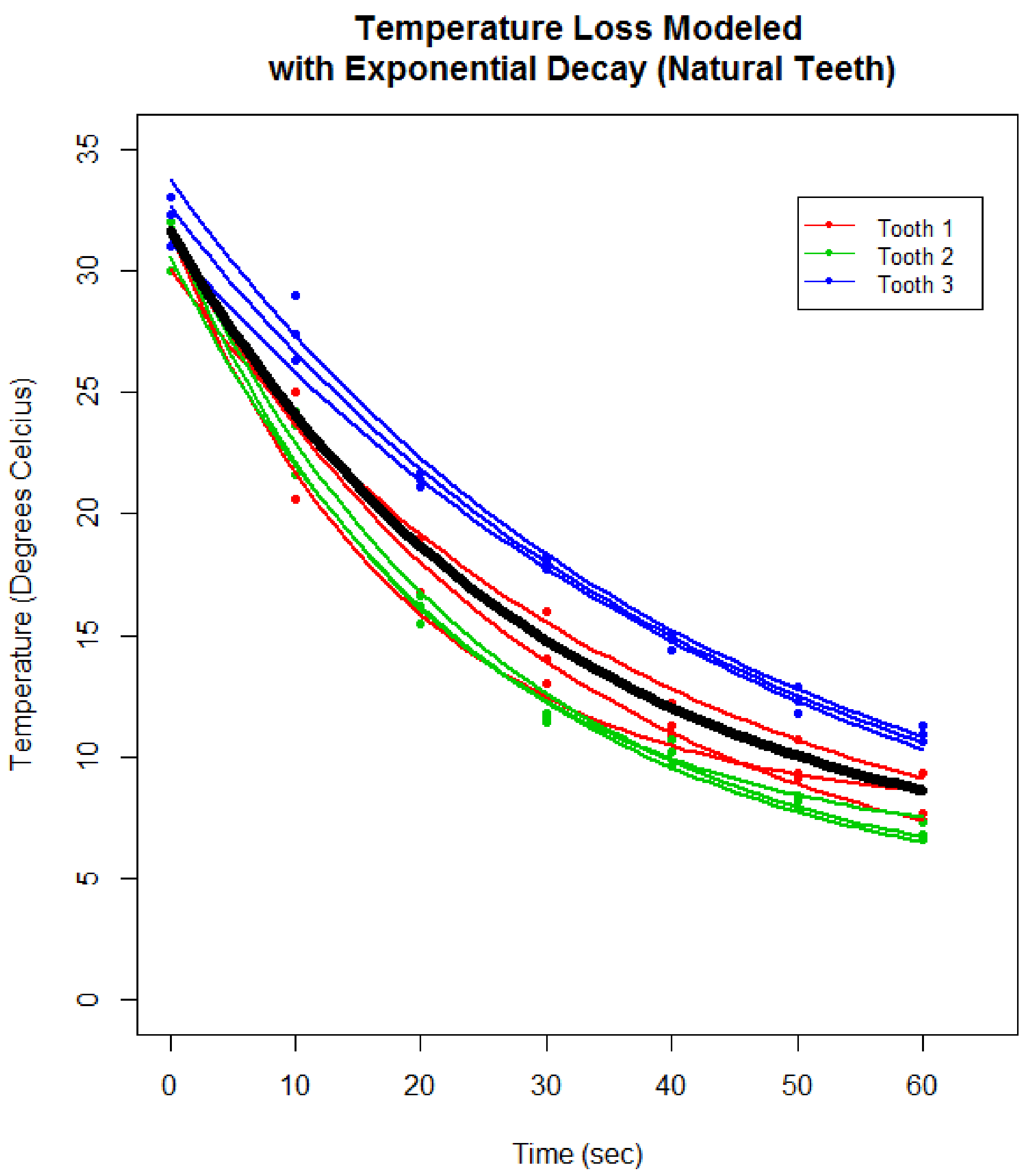
	10 seconds	30 seconds
Natural Teeth	Δ 6.8	Δ 13.1
IPS e.max	Δ 7.6	Δ 14.0
IPS ZirCAD	Δ 7.7	Δ 14.1
Vita enamic	Δ 6.8	Δ 12.9

Table 1: Shows the average change in temperature over 10 seconds and 30 seconds

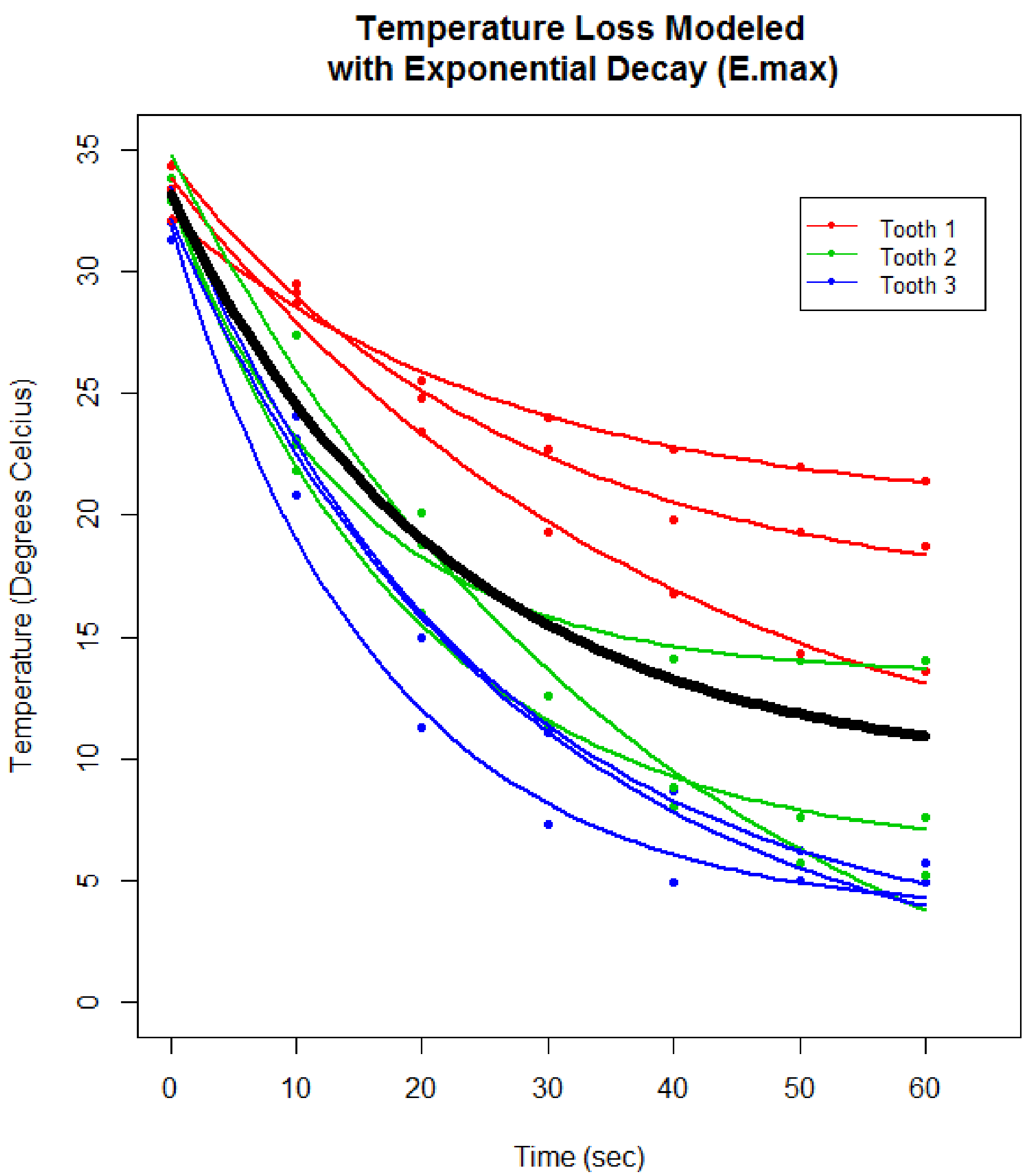
CHAPTER XI: GRAPHS



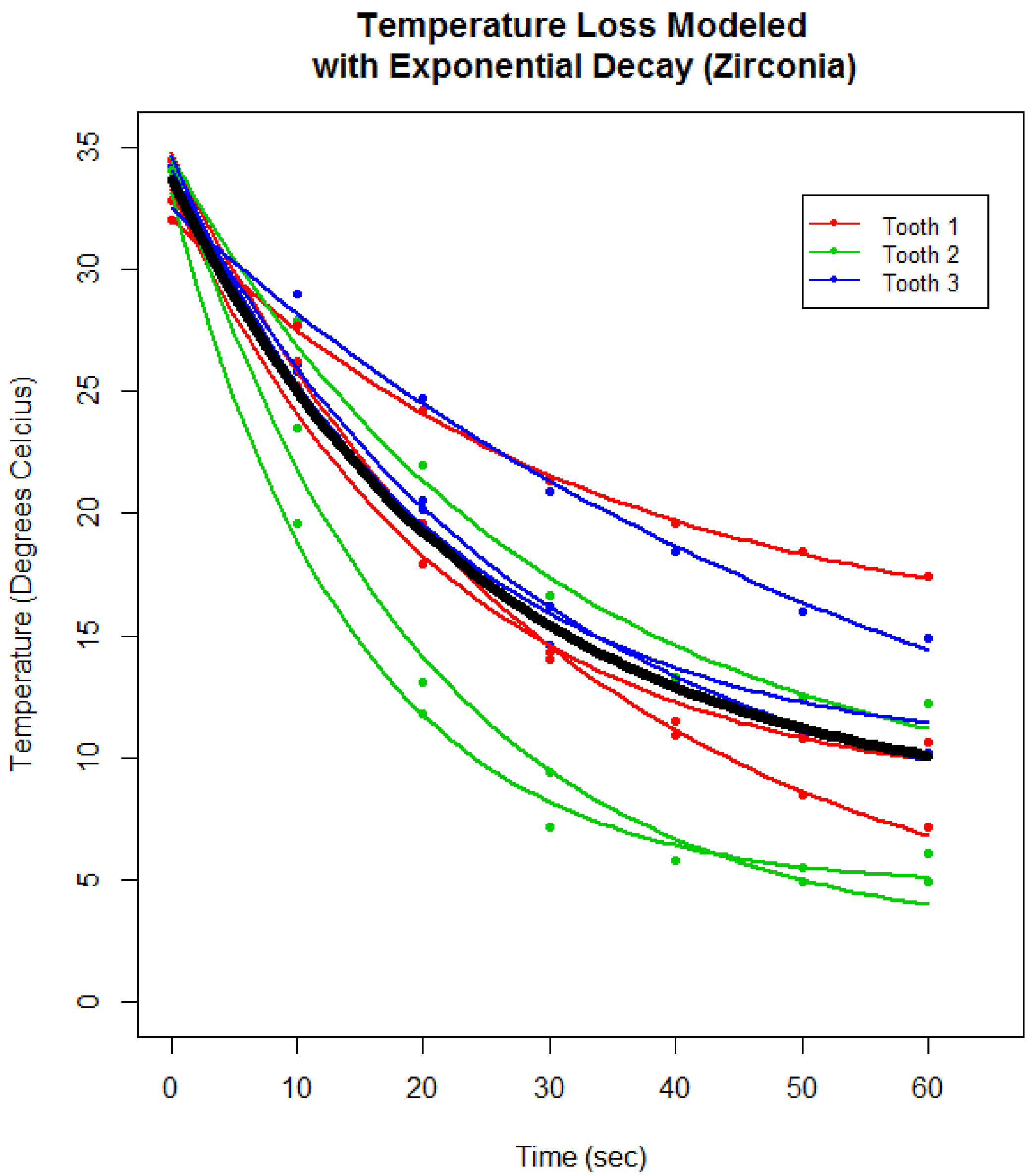
Graph 1: The average change in temperature in degrees Celsius over 60 seconds for the natural tooth and the restorative materials



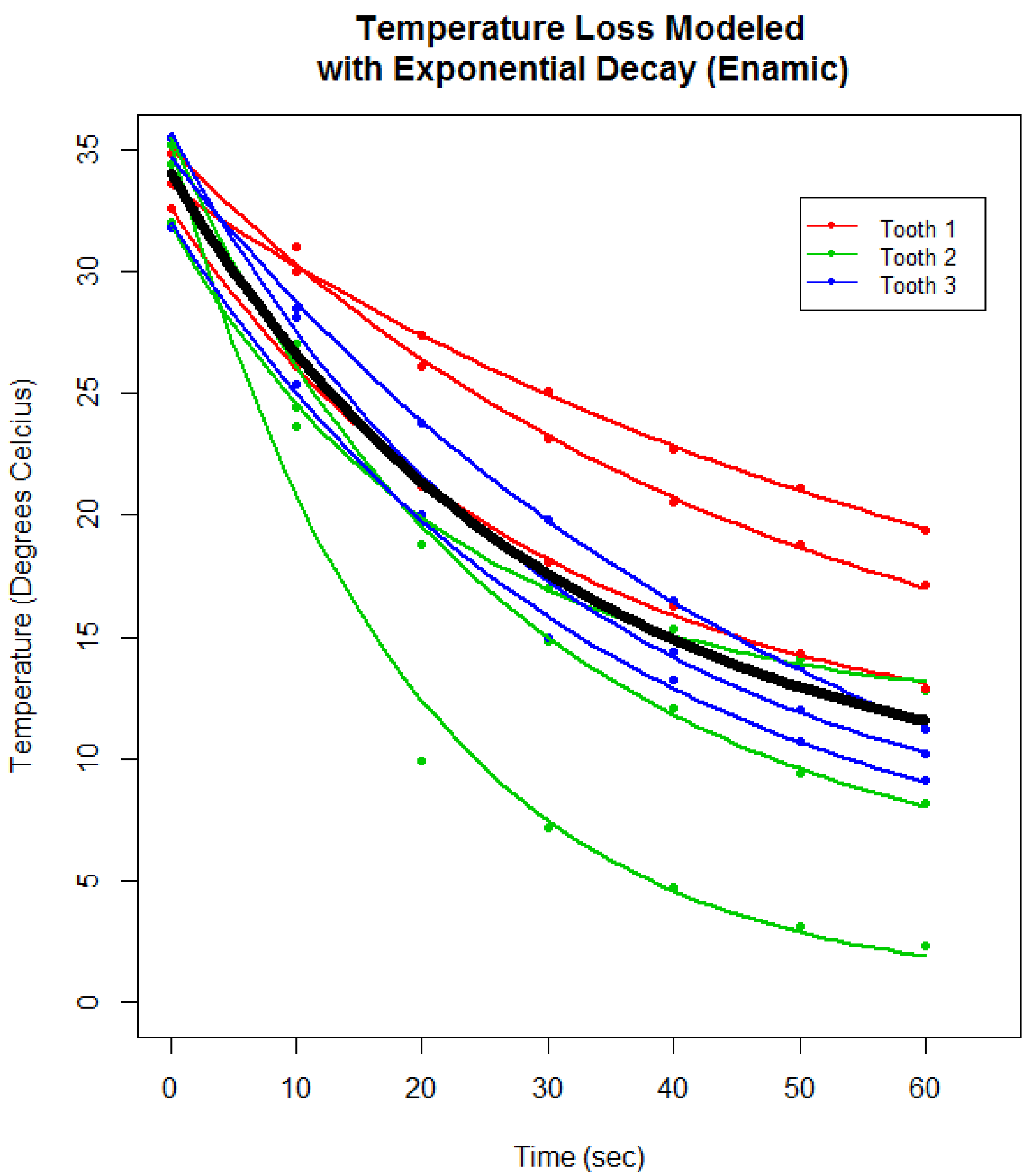
Graph 2: The change in temperature in degrees Celsius over 60 seconds for each tooth



Graph 2: The change in temperature in degrees Celsius over 60 seconds for each tooth with the e.max restorative material



Graph 2: The change in temperature in degrees Celsius over 60 seconds for each tooth with the zirconia restorative material



Graph 2: The change in temperature in degrees Celsius over 60 seconds for each tooth with the enamic restorative material